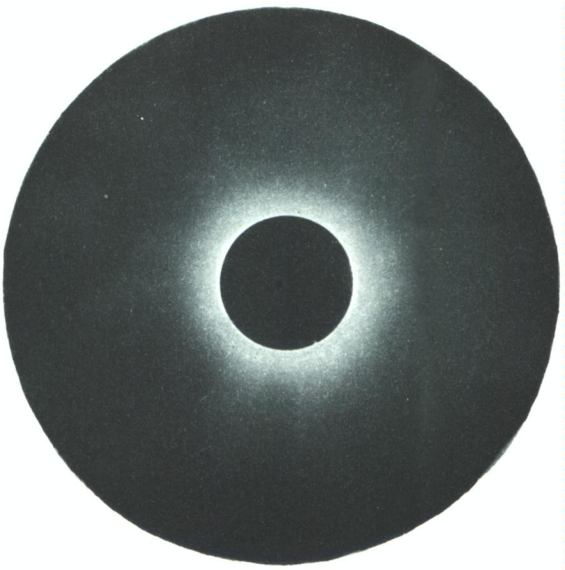


THE SOLAR CORONA
AUGUST 30, 1905
CROCKER ECLIPSE EXPEDITION
ALHAMA, SPAIN

THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION TO SPAIN.

By W. W. Campbell and C. D. Perrine.

The total solar eclipse of August 30, 1905, was looked forward to with unusual interest. Its duration,—three and three-fourths minutes as a maximum,—its occurrence at the season of the year when weather conditions would be the most promising, and the ease of access to widely separated observing stations on three continents, formed a favorable combination of rare occurrence. The eclipse would occur in Spain an hour and a half later than in Labrador; and in Egypt an hour later than in Spain. Here were offered just the opportunities desired to determine the existence and perhaps the character of motions within the coronal structure, and to search for possible intramercurial planets. To take suitable advantage of these rare opportunities required that well-equipped expeditions, working in harmony and cooperation, should be sent to each of the three countries mentioned. The subject was brought to the attention of Mr. William H. Crocker in July, 1904, who was quick to recognize the scientific importance of the event; and he at once made provision for meeting the expenses of the three large expeditions, as planned.[1] Preparation of the apparatus commenced at once and continued uninterruptedly until June, 1905.

With the approval of the Board of Regents of the University, the Labrador expedition[2] was dispatched in charge of Acting Astronomer Heber D. Curtis; the Spanish expedition in charge of Director Campbell, with Astronomer C. D. Perrine as associate; and the Egyptian expedition in charge of Astronomer W. J. Hussey.[3]

The path of totality, about one hundred and twenty miles wide, crossed northern Spain in a northwest-southeast direction. The cities of Oviedo, Burgos, Soria, and Daroca are

[1] Mr. Crocker's generosity in sending eclipse expeditions from the Lick Observatory, University of California, to Georgia in 1900, to Sumatra in 1901, and to Labrador, Spain, and Egypt in 1905, is recognized wherever astronomical literature travels.

[2] Dr. Curtis's account of this expedition was published in these *Publications*, No. 105.

[3] Astronomer Hussey's report follows in the present number of these *Publications*.

a few miles north of the center line of the path. Logroño and Zaragoza are a few miles within the northern edge of the shadow, and La Coruña and Valladolid are a few miles within its southern edge. Valencia appears to be located almost exactly on the southern edge. Excellent maps of the eclipse path, on both large and small scales, prepared by the Madrid Observatory and published by the Spanish Government, were very useful to observers in deciding upon their observing stations. Director IÑIGUEZ, of the Madrid Observatory, kindly placed at the disposal of observers a considerable quantity of meteorological data, notably the observations for 1897 and 1898, in order that they might judge of the weather probabilities. The best promise for a large number of clear days, small rainfall, low humidity, and small diurnal range of temperature seemed to be afforded by the region south and southwest of Zaragoza. Burgos, with slightly poorer weather conditions, as shown by the records, was to be the destination of numerous expeditions, as well as the objective point of the tourists,—good and sufficient reasons for our avoidance of it. A consideration of all the conditions, several months before leaving Mt. Hamilton, led to the decision that the expedition should locate in the Almazan-Ateca-Daroca region.

The scientific apparatus and supplies for the three expeditions were packed on the first three days of June for shipment by wagon to San Jose, thence by railway to Galveston and Gulf steamer to New York.

Mr. and Mrs. CAMPBELL, Mr. and Mrs. PERRINE, and Volunteer Observer THOMAS E. MCKINNEY, Professor of Mathematics and Astronomy in Marietta College, Ohio, sailed from New York on July 6th, per White Star steamer "Romanic," bound for the Azores, Gibraltar, Naples, and Genoa. The freight for the Spanish and Egyptian expeditions was on the same ship. The passage was an especially favorable one, as there was neither wind nor wave until the day before reaching Gibraltar. Nevertheless, the steamer's schedule was not maintained. The arrival at Gibraltar was a day late, which caused only minor inconveniences; but the delay in reaching Genoa was more serious in its consequences.

Mr. and Mrs. CAMPBELL disembarked at Gibraltar and journeyed overland to make necessary official arrangements

at Madrid, to select and prepare the site for the observing station, and to provide living accommodations. They stopped a day at Granada to see the Alhambra and other historical and architectural interests of this city, but, with eclipse duties ahead of them, they were in no mood for sightseeing. The other members of the expedition continued on the same ship, first to Naples, where Professor HUSSEY received in person the Egyptian freight, and thence to Genoa, where transfer to a steamer sailing direct to Barcelona was to be made. Unfortunately the belated arrival at Genoa vitiated the arrangements kindly made by the American Consul for a quick transfer to the Barcelona steamer, for which there should have been abundant time. This failure to make connections involved a delay of one week at Genoa, a loss that could ill be afforded at the observing station. Passage was secured on the steamer "Jativa," leaving Genoa on July 27th and reaching Barcelona on Saturday evening, July 29th.

The freight having been seen on board a railway car, Mr. and Mrs. PERRINE proceeded to the eclipse station, arriving on August 2d. Dr. MCKINNEY traveled on the train which carried the instruments, keeping watch on the eclipse car to guard against delays. He brought the car to its destination on the morning of August 3d.

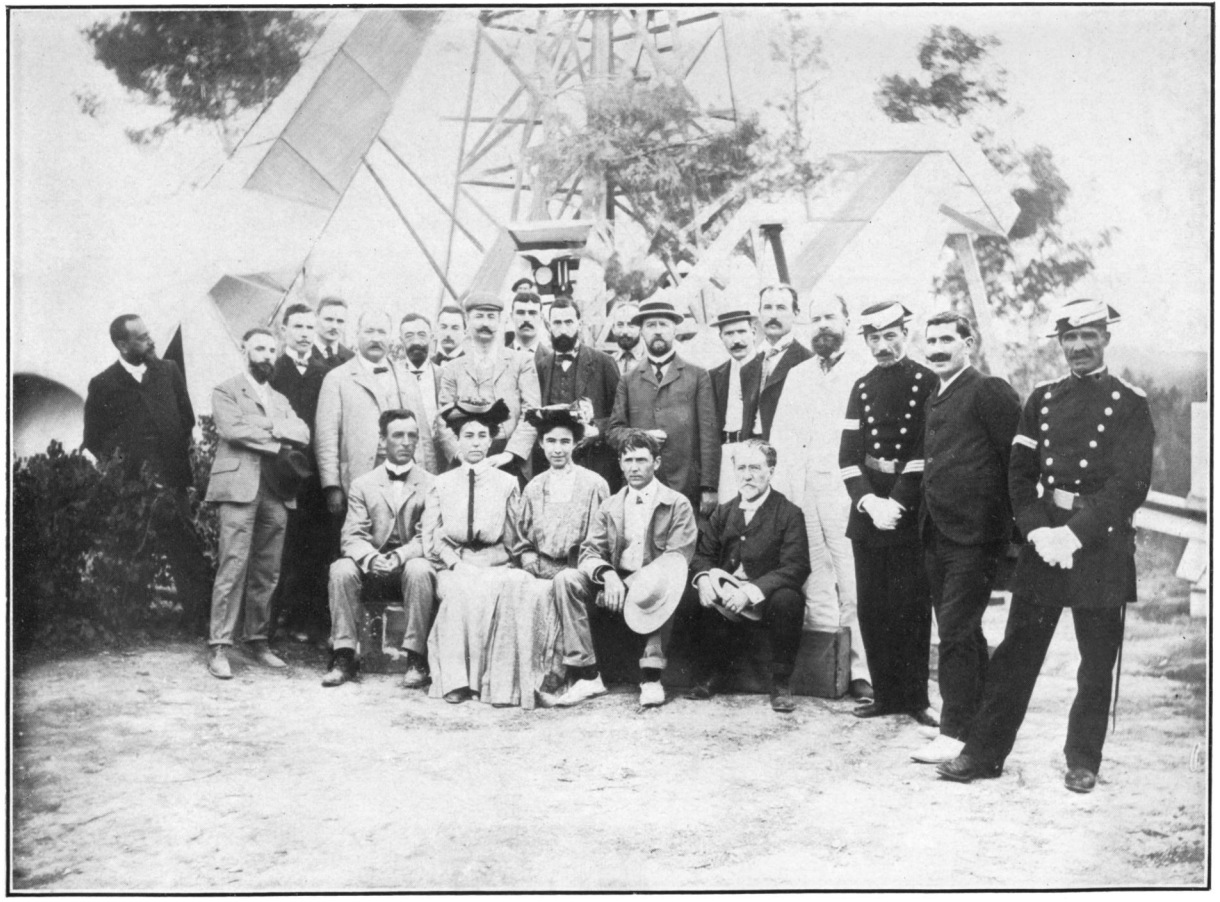
The main line of railway from Madrid to Zaragoza crossed the central line of the shadow-belt at the village of Alhama, in Aragon. This place is justly famous for its wonderful springs of warm water. Its baths were known to and patronized by the Romans in the days of the Roman occupation, and they continue to be used extensively in the late summer months by the Spaniards, for rheumatic and other complaints.

Interviews in Madrid with Professor CASARES, Astronomer IÑIGUEZ, and others led to the provisional selection of Alhama for the observing station. The weather indications seemed to be as promising there as anywhere along the line; no other expedition was planning to locate in Alhama; it was the point of easiest access for the imported instruments and for daily supplies, as well as for the assistants who were to come from Madrid, Zaragoza, and northern Europe; and there was a hotel with which arrangements for accommodations could be made. The latter point was of considerable importance, as

there were to be about twenty-five members of the expedition during eclipse week; and while food supplies in abundance had been taken from New York, in case it was necessary to establish our own camp, we were soon convinced that this should be avoided at almost any cost.

Mr. and Mrs. CAMPBELL reached Alhama on July 21st. This village of fifteen hundred people has an interesting location from the geological point of view. It is in a valley bounded for the most part by steep and conspicuously stratified walls of rock from two hundred to four hundred feet high. Near the center of the village these walls approach each other quite closely, so that the form of the town is roughly that of an hour-glass, whose length lies southwest and northeast. The fertile floor of the valley is subject to severe floods, and could not be thought of in connection with a site for observations. After careful search of the surrounding country, a satisfactory location was found near the southernmost part of the village, on a small hill rising about sixty feet above the valley. Some forty years ago a *palacio real* had been built, an artificial lake constructed, and the surrounding grounds improved to supply accommodations for the King, who was coming to take the baths. The hill referred to is in the palace grounds. It is fairly well covered with pine trees, especially on the slopes lying below the lines of sight of the instruments at the time of the eclipse. It is easy of access and, equally important, easily closed to inquisitive visitors. It was therefore definitely decided, on July 24th, to locate here. A half-dozen large rooms in a thick-walled masonry house, perfectly adapted to mechanical and photographic work, were found near the foot of the hill. Satisfactory arrangements were made with Hotel Los Termas for the accommodation of the party. During the following nine days, while waiting for the other members of the expedition to arrive with the instruments, laborers were employed in repairing the road to the summit, making the excavations, constructing the brick piers, and providing for the water and other supplies.

These preliminaries having been arranged, the assembling, mounting, adjusting, and testing of the instruments proceeded rapidly from the date of their arrival. We were fortunate in having the assistance of Dr. MCKINNEY and Dr. R. S. DUGAN,



THE OBSERVERS, ALHAMA, SPAIN.

formerly Assistant in the Heidelberg Observatory and now of Princeton University, throughout the entire period of work, from unpacking to repacking. Professors SVANTE ARRHENIUS and GUSTAF KOBB, of Stockholm University, were with us for ten days following August 20th. Mr. C. M. OLMSTED, an American student in Bonn University, was with us from August 25th to September 1st, and Mr. FREDERICK PALMER, Jr., of Haverford College, from August 27th to September 3d. To these six gentlemen the expedition is under special obligations. Even with their skillful assistance the work of preparation was exceedingly strenuous. We were able to obtain excellent unskilled laborers, but we found it expedient to be our own carpenters and machinists.

The available weather records for past years gave promise of very light rainfalls in the months of July and August. This promise was realized in August, but not in July. From July 21st to August 2d there were six heavy rainstorms, and the fall probably amounted to seven or eight inches. These storms were reported to be of wide extent in northeastern Spain, causing serious floods in many quarters. During the period August 2d to September 1st the weather conditions were excellent for erecting and testing the apparatus. There were sprinkles or slight showers on August 4th, 10th, 23d, and 25th, which caused no damage and little inconvenience. Nearly all the nights and forenoons were clear. The majority of the afternoons were clear, but there was a marked tendency for thin clouds to form in the early afternoon. On many days the sky was beautifully blue and markedly free from glare around the Sun. The Milky Way frequently shone as we have seldom seen it except on Mt. Hamilton.

The other volunteer assistants who were to take part in the observations arrived at Alhama on August 27th and in the morning of August 28th. They were: Professor Dr. J. HARTMANN, Astrophysical Observatory, Potsdam; Sr. D. ERNESTO GREVE, National Observatory, Santiago, Chile; Dr. VIGGO STRÖYBERG, formerly in the observatory, Copenhagen; Sr. D. ARTURO CUYÁS, Madrid; Professor JOSÉ CASARES, Central University, Madrid; Professor HILARIÓN GIMENO, University of Zaragoza; Professor ANTONIO ROCASOLANO, University of Zaragoza; Professor FELIPE LAVILLA, University

of Valencia; Lieutenant MANUEL HERNANDEZ, Geodetic Survey, Madrid; Sr. D. ESTEBAN TERRADAS, University of Madrid; Sr. D. ENRIQUE IBAÑEZ, Secretario de Municipalidad, Alhama; Sr. D. FELIPE HERREROS, Telegraphico, Alhama; Sergeant ESTEBAN BARBAJOSSA, Guardia Civil de Espagna; Sr. JUAN BLASCO, Guardia Civil de Espagna.

The remaining days were devoted to training the twenty-four observers to their duties at the instruments, to testing the final adjustments, to preparing the photographic plates and their holders, and to arranging the multitude of details which affect success.

Threatening weather conditions arose on the evening of the 28th. From early morning of the 29th until late in the afternoon the wind blew a veritable gale and the sky was thickly clouded. Although the ground at the station was thoroughly sprinkled, the wind brought clouds of dust from a distance. The rehearsals of programme were made very difficult, and the situation was discouraging. However, the wind ceased and the sky cleared in the early evening.

The night of the 29th and the forenoon of the 30th were as perfect as any during our stay in Alhama. About noon of the 30th clouds began to form here and there; by 12:30 they were numerous, especially in the northwest; and before 1:00 a sheet of light mackerel clouds was streaming southeasterly across the Sun. During totality,—from 1:11 to 1:15, Greenwich mean time,—the principal prominences and the general features of the corona were visible through the thin clouds. The clouds probably permitted from twenty to thirty per cent of the photographic rays to pass. The lower atmosphere was perfectly calm; not a breath of air was stirring.

All preparations were completed, and the observers were in their places, several minutes before totality began. Signals "5 minutes," "1 minute," and "20 seconds" were given by Mr. OLMSTED at the timepiece. Certain of the spectrographic exposures were to begin at "12 seconds" before the computed time of total eclipse. Totality began about 17 seconds earlier than the computed time, on which account the few affected spectroscopic exposures were necessarily omitted; but all the exposures after the beginning of totality were secured as planned.

Much has been tried for at this eclipse, and the presence of clouds was a severe discouragement. Nevertheless, considerable confidence was felt that sufficient light had penetrated the clouds to give useful results with most and perhaps all of the eighteen instruments. Development of the plates on succeeding days showed that the coronal photographs were most excellent,—the "seeing" had been good; that nearly all the spectrograms were of splendid quality; but that the intramercurial plates and those spectrograms which demanded all the light from an unclouded sky were only partially successful.

Mathematical astronomers have made comparatively little use of eclipse contact-time observations for improving our knowledge of the Moon's motion. The expense and time involved in transporting, erecting, and using meridian instruments for the purposes of the three expeditions seemed unjustified, and it was accordingly decided to depend upon sextant observations of the Sun, not only for time, but for latitude determinations also. In Labrador the eclipse-path lay due east and west, and a knowledge of the *longitude* was an unimportant consideration so far as selecting a station was concerned. It was known that His Excellency, Governor McGregor of Newfoundland, a geodesist of considerable experience, was to make a latitude and longitude expedition to the eclipse stations[1] in the month of August. From the large-scale maps of the Aswan district, kindly sent to the Lick Observatory by Captain H. G. Lyons, R. E., Director-General of the Egyptian Survey, it was also evident that the latitude and longitude could with confidence be taken directly from the charts. The transportation of chronometers on long railway journeys is attended with considerable risk, and it was thought that good watches would be satisfactory substitutes. Through the kind offices of Mr. F. H. McConnell, of San Francisco, eleven watches were sent to Mt. Hamilton late in 1904 for trial. Three Elgin watches were selected, whose performance compared very favorably with that of standard chronometers when they were handled with the same care that chronometers demand. One of these watches was sent with each expedition.

It is probable that observations of the Sun, secured with

[1] For an account of his work at the Lick Observatory-Crocker station in Labrador, see these *Publications*, No. 105, p. 178.

sextant and watch, before and after the eclipse, furnish time for the eclipse as accurately as observations with transit and chronometer made on the stars during the preceding and following night, especially if there are considerable changes in temperature from night to day and day to night.

When Mr. CAMPBELL was in Madrid he arranged with Director IÑIGUEZ to send electric time-signals from the standard clock of the Madrid Observatory to the eclipse station. Through the kindness of the telegraphic service these signals were received satisfactorily on several dates between August 3d and August 16th, inclusive. The longitude as obtained from these signals and the local time observations, the latitude obtained from circum-meridian altitudes of the Sun, and the altitude above sea based upon the figures published for the railway at Alhama, are

Longitude $= 7^m\ 36^s = 1^\circ\ 54'\ 00''$ W. of Greenwich.
Latitude $= +41^\circ\ 17'\ 40''$.
Altitude = 2,200 feet = 670 meters.

The station was almost exactly on the central line of the shadow.

The computed times of beginning and ending of totality, based upon American Ephemeris data, determined by Messrs. KOBB, OLMSTED, and CAMPBELL, were

II, $1^h\ 11^m\ 23^s$, Greenwich M. T.
III, 1 15 08 " "

The signal that totality was complete was given by Mr. PERRINE, based upon naked-eye observation, at $1^h\ 11^m\ 07^s$, Greenwich mean time. Dr. DUGAN, who was observing the diminishing crescent on the plate-holder of the 40-foot camera, estimated that totality occurred between one and two seconds earlier. We think it is entirely possible that the very bright prominence near the point of second contact may have influenced the naked-eye observation, and $1^h\ 11^m\ 06^s$ is perhaps the time to be adopted. The Sun reappeared at $1^h\ 14^m\ 45^s$. The duration was therefore $3^m\ 39^s$, or six seconds less than that given by the American Ephemeris. Totality began 17 seconds earlier and ended 23 seconds earlier than the predicted times. The middle of the eclipse thus occurred 20 seconds earlier than expected. There seems to be no escaping the fact that the

Moon was far ahead of its predicted right ascension. Time-signals received on six days directly from the Madrid Observatory made a serious discrepancy in the adopted longitude impossible, and it agrees exactly with that read off from the excellent large scale map of the Province of Zaragoza prepared by the Geographical Engineers, and presented to us by the Government of Zaragoza. Very accordant sextant observations for time had been secured at 8:10 A. M., 10:40 A. M., and 3:10 P. M. of the eclipse day, and this element could not be in error by as much as one second.[1]

This was a "dark" eclipse, notwithstanding the light diffused by the clouds. It was very much darker than those of India, 1898, and Georgia, 1900, and darker than that of 1901 in Sumatra. The amount of cloudiness at the two stations in 1901 and 1905 was not very different. At the former eclipse Mr. PERRINE could read the figures in a table of logarithms easily, while at the latter he had to look closely to distinguish them.

The eighteen instruments of observation were mounted in six groups, each group depending upon one driving-clock. The six groups were so situated that all the observers could hear the time-counter, who occupied a central position with reference to them.

TIME SIGNALS.

In charge of Mr. CHARLES M. OLMSTED.

Each of the three expeditions was provided with a pendulum, consisting of a rod and a heavy flat lead disk, which could be adjusted to one-second period. The Spanish pendulum, supported by a stout bracket on a heavy timber post, was set in motion shortly before totality. Beginning with the swing following the signal for totality, Mr. OLMSTED counted "One, two, three, four, . . ." until, after the reappearance of the Sun, the pendulum counts had been compared twice with the watch and recorded. This method was entirely satisfactory.

FORTY-FOOT CAMERA.

In charge of Dr. DUGAN, assisted by Professor LAVILLA.

The outside general features of this instrument, designed by Professor SCHAEBERLE for observing the eclipse of 1893,

[1] After this was written, a number of preliminary eclipse accounts of other expeditions have come to hand, and many of them noted that totality occurred some twenty seconds earlier than predicted.

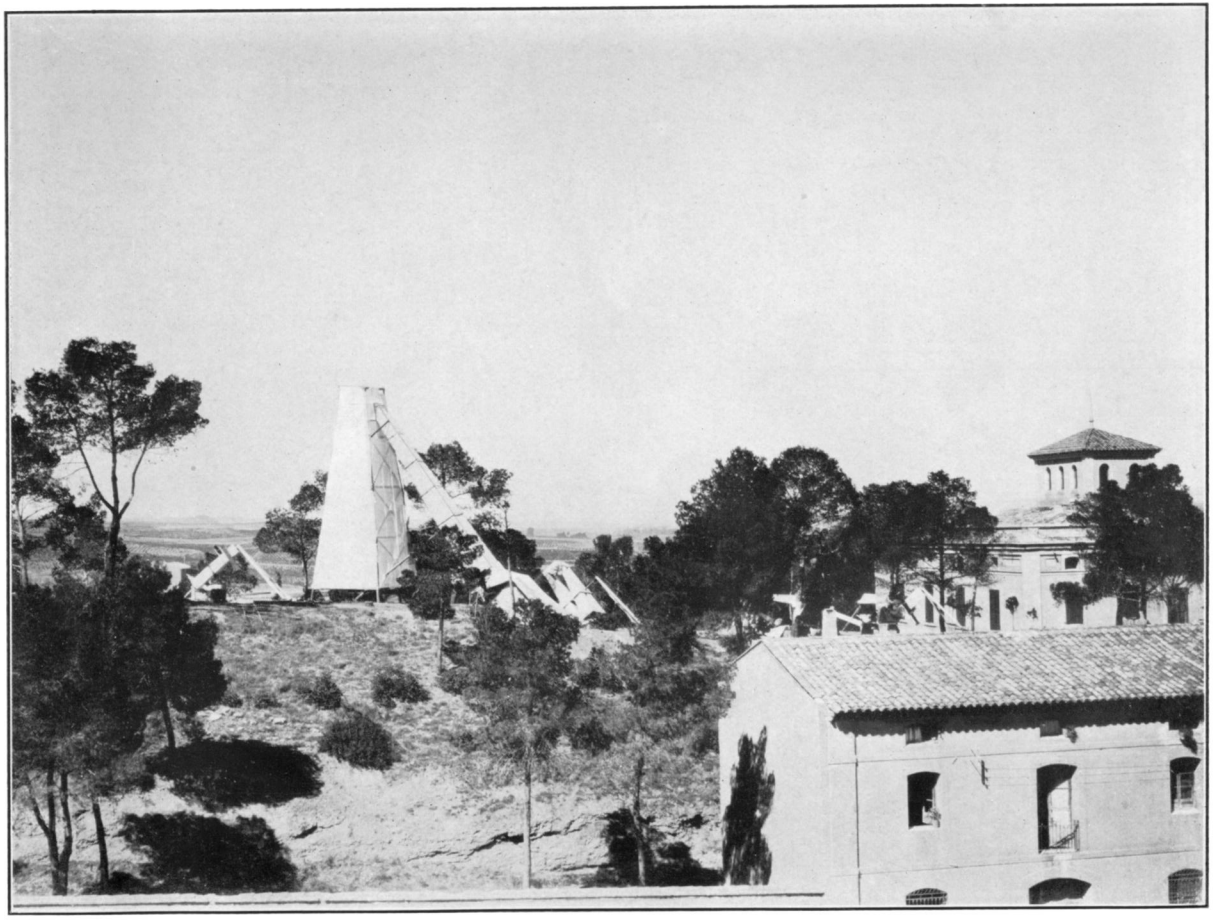
are shown in the reproduced photograph of the station. In this camera the Clark lens of 5-inch aperture, the combination tube of iron and cloth, and the plate-carriage moving by clockwork on an accurately curved metal track, are supported entirely independently of each other. The lens is mounted on the top of a strong interior tower, surrounded by a cloth-covered outer tower, whose duties are to support the upper end of the camera tube and to prevent the wind from shaking the inner tower; a system of lens support devised by Mr. CAMPBELL to meet conditions on the plains of India in 1898. With this form of support the camera can easily be pointed near the zenith if necessary (as in Sumatra by Mr. PERRINE in 1901); and the advantage of having the lens at a good height above the radiating soil is preserved. The towers are easily constructed, the various parts of the camera are quickly put into their approximate positions from simple computations, and the final adjustments are readily made.

The Sun's altitude at Alhama was 55°, and the center of the lens was 32 feet 8 inches = 9.96 meters above the center of the photographic plate.

Ten exposures were made on Seed No. 27 plates, as follows:—

No. 1,	½	second,	before	count	"one"			
2,	1	"	from	0^m	07^s	to	0^m	08^s
3,	4	"	"	0	14	"	0	18
4,	8	"	"	0	24	"	0	32
5,	64	"	"	0	44	"	1	48
6,	64	"	"	1	58	"	3	02
7,	8	"	"	3	12	"	3	20
8,	2	"	"	3	25	"	3	27
9,	1	"	"	3	35	"	3	36
10,	½	"	"	3	41	"	3	41½

The two 64-second exposures were on plates 18 × 22 inches, and the other exposures on plates 14 × 17 inches. Plates Nos. 4, 5, and 9 had "standard square" exposures made near one corner of each of them at Mt. Hamilton in May by means of a Hefner amyl-acetate lamp, kindly loaned for the purpose by the Department of Physics of the University of California.



GENERAL VIEW OF THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION, ALHAMA, SPAIN.

These squares are intended as a basis for a photometric study of the coronal images.

When the negatives were developed we were relieved to find that the clouds had exerted no bad effects upon their quality: the obscuration had simply reduced the effective coronal intensity without spoiling the definition. The "seeing" had been good, and the negatives were of great excellence. The longer coronal streamers were recorded out to about one solar diameter from the Sun's edge. The details of the great prominences on the eastern limb, of a few of the smaller prominences, of the coronal arches over the prominences, and of the coronal structure are of great interest. The streamers were, in general, of substantially equal lengths at all points of the solar limb. Those of more than average lengths seemed not to be specially related to the great streamers visible at times of sun-spot minima. The present corona was a "maximum" one. An attempt has been made to reproduce one of the one-second negatives by heliogravure process, in the accompanying illustration. The great prominence is shown, though with serious loss in sharpness, but the rich details of coronal structure are completely lost. It seems impossible to reproduce coronas by mechanical processes, with any approach to justice to the subject.

THE WM. M. PIERSON CAMERA,
In charge of Sr. D. CUYÁS and Professor CASARES;
AND THE FLOYD CAMERA,
In charge of Professor GIMENO and Sr. D. TERRADAS.

The former of these has a Dallmeyer quadruplet objective, aperture 6 inches and focal length 33 inches. The latter has a Clark objective, 5 inches aperture and 67 inches focus. Both cameras were mounted on a clock-driven polar axis, which also carried two spectrographs, to be described later.

Seven exposures were made with each camera, the exposures with the two instruments beginning and ending at the same instants to avoid jarring. They were as follows, on Seed plates No. 27:—

No. 1,	2 seconds	No. 5,	16 seconds
2,	8 "	6,	4 "
3,	32 "	7,	2 "
4,	64 "		

These negatives have recorded the longer coronal streamers out to a distance of about two solar diameters from the limb of the Sun. They likewise were not injured by the clouds, and they will be very valuable in a study of the middle and outer coronal forms. The attempted reproduction of one of the Floyd negatives shows only the general features of the corona, and fails completely to reproduce any of the exquisite detail of the original.

THE INTRAMERCURIAL-PLANET CAMERAS.

In charge of Mr. PERRINE, assisted by Messrs. GREVE, IBAÑEZ, HERNANDEZ, and HERREROS.

The search for an intramercurial planet was to be carried on with lenses exactly similar to those used at the Labrador and Egypt stations and to those used in Sumatra in 1901: 3 inches aperture and 11 feet 4 inches focus, constructed by ALVAN CLARK & SONS. The region to be photographed comprised an area 29° long, in the direction of the Sun's equator, by 9¼° wide. The Sun was in the center of this region. Four cameras were fastened together rigidly and mounted on a clock-driven polar axis so as to cover the entire region, using plates 18 × 22 inches in size. Two sets of exposures as long as possible furnished duplicate plates for the detection of defects.

The programme was carried through at the time of the eclipse as planned. The clouds interferred to such an extent, however, that it is not believed that the photographs will add anything to the results obtained at the Sumatra eclipse. The negatives have not yet been closely examined.

The intramercurial apparatus is shown, in the illustration of the camp, to the right of the 40-foot camera, though on a small scale. The corresponding apparatus of the Labrador expedition is shown, on a larger scale, in these *Publications* (No. 105, p. 180), and that of the Egyptian expedition in the present number (p. 37). The three mountings were designed by Mr. PERRINE and constructed under his immediate superintendence. They were very rigid and worked well.

OBJECTIVE-PRISM SPECTROGRAPH WITH STATIONARY PLATES.

In charge of Professor HARTMANN.

The purpose of this instrument was to secure a series of photographs of the changing spectrum of the Sun's edge at

and near the times of beginning and ending of totality, in accordance with the method first used successfully by Mr. SHACKLETON at the eclipse of 1896. The spectrum of the reversing layer, i. e. the "flash spectrum" near the beginning and end, was especially desired.

The optical parts of the instrument consisted of two objective-prisms of moderately dense flint glass, refracting angle 60°, refracting edges 2⅛ inches long, with faces 3¾ and 3⅞ inches long, respectively, placed immediately in front of a triple lens, aperture 2⅛ inches, focal length 60 inches, corrected for Hγ central. The plate-holder, holding seven Seed No. 27 plates, each 1¾ × 10 inches, was carried in a long slide. Brass racks fastened to the back of the plate-holder, and pinions supported by the slide and working in the racks, were the simple means of giving motion to the plate-holder. As soon as an exposure had been made on one narrow plate, one rotation of the pinions (by means of a small crank) brought the next narrow plate into position. The exposing shutter was a simple flap of zinc directly in front of the sensitive plate. The mounting of the instrument was of sugar-pine wood, and it was supported upon timbers set in stone and cement. The spectrograph received its light from the 15-inch plane-mirror of a cœlostat kindly loaned to the expedition by the Yerkes Observatory. The various parts of the instrument were adjusted to each other, and the instrument as a whole was adjusted to bring the Hγ region approximately to the center of the plate and the length of spectrum parallel to the edge of the plate several days before the eclipse. It was brought into final position a few minutes before totality.

In accordance with Mr. CAMPBELL'S instructions, it had been intended to make the first exposure several seconds before totality, to record the Fraunhofer spectrum, and to begin the second exposure at three seconds before totality, to record the flash spectrum. The coming of totality 17 seconds before it had been expected interfered with carrying out this programme, but fortunately Dr. HARTMANN, who was watching the progress of the eclipse with a small hand spectroscope, recognized its earlier arrival, and made his first exposure three seconds before totality, with estimated duration $0^s.4$. Development of the plate showed that the photosphere was still visible

on one section of the Sun's limb, but that the reversing layer was isolated from the photosphere on an adjoining section. The result is a magnificent photograph, showing the continuous and dark-line spectrum for one section and the bright-line spectrum (many hundreds of bright crescents) for the other section. The plate is in splendid focus from about λ 4800 to λ 3700. The Hβ bright line near one end of the plate is out of focus, unavoidably, just enough to make it clearly doubled.

The seven exposures made by Dr. HARTMANN were:—

No. 1, Exp. $0^s.4$, three seconds before totality.
2, " 0 .4, immediately after totality began.
3, " 60 .0, from $0^m\ 12^s$ to $1^m\ 12^s$.
4, " 120 .0, from 1 16 to 3 16
5, " 3 .0, after totality was over.
6, " 0 .4, " " " "
7, " 0 .4, " " " "

Plate No. 2 shows the high-level bright lines. Plate No. 5 is overexposed for the continuous spectrum, but shows the flash spectrum well on one side of the Fraunhofer spectrum.

A study of this very successful series of photographs, involving much labor, should supply extensive and accurate information as to the structure of the reversing layer.

OBJECTIVE-PRISM SPECTROGRAPH WITH MOVING PLATE.

In charge of Professor ARRHENIUS.

Photographs of the reversing-layer spectrum, taken in the usual manner with objective-prism instruments, such as that described in the preceding paragraphs, are integrated effects. Changes taking place during the exposure are not differentiated, and changes taking place between exposures are entirely lost. A continuous record of the changing spectrum is a great desideratum. A simple addition to the objective-prism spectrograph enables this to be obtained for a short length of solar limb. The usual reversing-layer spectrum consists of a series of crescents, each crescent an image of the uneclipsed portion of the Sun. A slit running centrally through the spectrum, placed all but in contact with the photographic plate, permits

a short central section of each crescent to fall upon the plate. If the plate is given a slow continuous motion by suitable mechanical means, a fresh part of the plate will be brought under the slit, and the changing spectrum will be recorded continuously. This method was devised and used by Mr. CAMPBELL in India in 1898 and in Georgia in 1900. At the latter eclipse an exposure beginning about 10 seconds before the end of totality, and continuing until 12 seconds after totality was over, recorded more than nine hundred bright lines and their succeeding dark lines.

The instrument used by Professor ARRHENIUS was equipped in the manner just described. The two objective prisms were of moderately dense flint glass, Jena No. 0.102, refracting angle 63° 27′.5, length of refracting edge 2 inches, lengths of faces 3.47 and 3.95 inches, respectively. The triple lens had aperture 2⅛ inches and focal length 60 inches. The slit in front of the plate was 0.05 inch wide and 9½ inches long. The plate-holder was moved by a hydraulic piston actuated by a weight, modeled after the piston of the Potsdam spectroheliograph, The controlling valve was regulated to a speed of about 0.06 inch per second.

It had been intended to secure a moving photograph extending from 12 seconds before to 12 seconds after the instant of totality, and a similar photograph from 12 seconds before to 12 seconds after the end of totality. The first of these was prevented by the arrival of totality 17 seconds earlier than was expected, but the second exposure, extending from $3^m\ 33^s$ to $3^m\ 57^s$ after totality began, was entirely successful. The changing spectrum is shown admirably through all the phases from high-level strong bright lines, through the bright-line stage of the reversing layer, and into the ordinary dark-line stage. There are six or eight hundred lines recorded in the region $\lambda\ 3800 - \lambda\ 5200$, with $H\gamma$ central on the plate.

During totality the slit in front of the plate was rotated to one side of the field of view, and the full prismatic image fell on the plate, from 1^m to 3^m after the beginning of totality. The coronal rings at $\lambda\ 4231$ and $\lambda\ 3987$ are strongly recorded. For this exposure the plate was fixed in position.

This spectrograph also received its light from the Yerkes Observatory cœlostat mirror.

ULTRA-VIOLET SPECTROGRAPH, WITH MOVING PLATE.

In charge of Mr. CAMPBELL, assisted by Dr. KOBB.

In order to extend further into the violet the study of the reversing-layer spectrum with a continuously moving plate, a spectrograph was constructed whose optical parts should be efficient for ultra-violet light, as follows: Two objective prisms of Jena ultra-violet glass No. 3199, refracting angles 60°, refracting edges 60^{mm}, and lengths of faces 100^{mm} and 110^{mm}, respectively. A special lens of ultra-violet glasses, aperture 66^{mm} and focal length 2000^{mm}. A cœlostat mirror of Schroeder's metal No. 1, diameter 110^{mm} and thickness 15^{mm}, attached to the lower end of the Lick Observatory cœlostat's polar axis.

The foregoing parts were ordered from CARL ZEISS in October, 1904, delivery promised in February, 1905. As they did not reach Mt. Hamilton until the first week in June, after the necessarily unfinished wooden mounting was packed for shipment, the instrument was completed in Spain with time that could ill be spared for the purpose.

The plate-holder was moved by a weighted piston, as in the case of the preceding spectrograph operated by Professor ARRHENIUS.

This ultra-violet spectrograph is shown in position at the observing station in the accompanying illustration. The Lick Observatory cœlostat, seen in the same photograph, carries a 12-inch flat mirror by PETITDIDIER, as well as the Schroeder's-metal mirror.

The exposures planned for this spectrograph were identical with those for Professor ARRHENIUS'S instrument. Those actually made, on account of the earlier arrival of totality, were identical with his for the exposure with fixed plate, from 1^m to 3^m, and for the exposure with moving plate, $3^m\ 33^s$ to $3^m\ 57^s$. The thin clouds interfered with the passing of ultra-violet light; and while the record extends to perhaps λ 3200, the spectrum is weak in intensity, only the stronger ultra-violet lines being shown. The dispersion of the ultra-violet glass is very low; the linear dispersion of λ 3200 and λ 5200 is but 150^{mm} for the two 60° prisms and focal length of camera 2000^{mm}.

The exposure with fixed plate recorded two strong coronal

THE LICK OBSERVATORY CŒLOSTAT AND ULTRA-VIOLET SPECTROGRAPH, ALHAMA, SPAIN.

rings, at λ 3388 and λ 3456, which have been noted by several observers since 1898.

Great care was taken in focusing the objective-prism spectrographs, by the following method:—

A parabolic silver-on-glass reflector, diameter 10 inches and focal length 10 feet 2 inches, by PETITDIDIER, was mounted in a horizontal tube of seasoned wood, and pointed to the mirror of the cœlostat in such a position that the rays from a bright star (parallel light) would cover the parabolic mirror and be brought to a focus on its axis. This focal point was determined very accurately by photography. A spectroscope slit was then mounted with its surface exactly in this focus. An iron electric spark from electrodes a few inches out from the slit was focused on the slit. The cone of rays passing through the slit completely covered the parabolic mirror. The spectrograph to be focused was mounted with its first prism just to one side of the slit so that the (parallel) rays from the mirror would cover the prism, and the ray of desired wave-length be brought to the center of the photographic plate. The usual methods of focusing the plate were then applicable. The entire process worked well and was exceedingly convenient.

OBJECTIVE GRATING SPECTROGRAPH.

In charge of Dr. KOBB.

This instrument, shown just beyond the ultra-violet spectrograph in the illustration, received its light from the Lick Observatory cœlostat. A plane Rowland grating, 14,438 lines to the inch, set for the third order, received the light, and returned it through a (visual) camera-lens 2⅛-inch aperture, 20½-inch focal length, to a Cramer's isochromatic plate. The region of the green coronal ring at λ 5303 was central in the field. A yellow-green color-screen was fastened immediately in front of the plate to cut out the overlapping spectrum. The purpose of the exposure, extending throughout the total phase, was to record the green ring, in order to determine whether the layer giving rise to its light was uniformly distributed around the Sun, or not. Owing partly to the clouds and partly to the light-consuming properties of the optical train, the image of the ring secured is exceedingly faint, and not much can be said from it as to the law of distribution, but there is little doubt that the ring is of quite irregular intensity.

The distribution at other recent eclipses, at times of sun-spot minimum, was exceedingly irregular.

THREE-PRISM SLIT SPECTROGRAPH.

In charge of Mr. PALMER.

The purpose of this instrument was to determine the wave-length of the green coronal line near λ 5303. It was mounted on a clock-driven polar axis, pointed directly toward the Sun, and received its light from an image-lens (visual) of aperture 1½ inches and focus 10½ inches. The slit-jaws were curved to a radius of 3.30 inches to make the recorded spectrum lines straight for ease and accuracy in measurement. It was placed east and west across the Sun's image. The collimator-lens (visual) was of 2⅛-inch aperture and 20½ inches focus. The three extra dense flint prisms had refracting angles of 60°, refracting edge 2⅛, 2¼, and 2¼ inches, respectively, and length of faces 3⅝ inches. The deviation for λ 5303 was 169° 36′. The triple camera-lens (visual) had aperture 2⅛ inches and focal length 20½ inches. A movable diaphragm in front of the slit had six holes so arranged that the coronal spectrum from the east limb of the Sun would have a sky spectrum on either side of it for comparison, and similarly for the coronal spectrum on the west limb.

The images of the green line on the plate, exposed throughout totality, are likewise very faint, and capable only of approximate measurement.

SINGLE-PRISM SPECTROGRAPH.

In charge of Mr. PALMER.

This instrument was mounted beside the one just described, and received its light in the same way. Its purpose was to record the general spectrum of the corona.

The image of the Sun on the slit was formed by a lens of 1⅝-inch aperture and 13 inches focus. The collimator-lens was of 2 inches aperture and 32 inches focus, corrected for Hγ. The prism was of Jena glass No. 0.102, angle 63° 27′, refracting edge 2¼ inches, length of face 4.55 inches. The camera-lens was of aperture 2 1/16 inches and focal length 12 inches, corrected for Hδ. The region between Hγ and Hδ occupied the center of the field.

The exposure continued throughout the total phase. The

spectrum is strongly recorded. That of the inner corona shows no Fraunhofer dark lines, whereas they are strong in the spectrum of the outer corona. They are also shown, less strongly, on the area occupied by the Moon. It is thus clear that our own atmosphere, or perhaps the clouds, diffused the light to a considerable extent, and the results are more difficult to interpret on that account.

THE POLARIGRAPHS AND PHOTOMETER.

In charge of Professor McKINNEY, assisted by Professor ROCASOLANO, MTS. CAMPBELL, MRS. PERRINE, and SRS. BARBAJOSSA and BLASCO.

The observations of the polarized light in the corona of 1901, with a double-image prism, were very successful. Owing to the dispersion of the prism, however, and to the small scale of the images, it was not possible to measure the intensities with the necessary accuracy for determining reliable values of the polarization. In addition to the double-image camera, which was again used, new apparatus was designed by Mr. PERRINE for polarization observations at the recent eclipse. Three cameras composed this apparatus. Two of these had plane-glass reflectors in front of the objectives to serve as analyzers, while the third camera was used to secure an unpolarized image of the corona as a standard of comparison. The aperture of this direct camera was reduced so that the image obtained with it would be of approximately the same intensity as an (*unpolarized*) image with the other two cameras, after reflection from the plane-glass surfaces. The plane-glass analyzers were set at the angle of maximum polarization. Their principal axes were adjusted, one parallel to a north-and-south line and the other to an east-and-west line, through the corona. In this way polarization was observed along four different radii of the corona. The three cameras have focal lengths of 50 inches, which give images of the corona 2½ times the diameter of that obtained with the double-image camera. The four polarigraphs were mounted on one polar axis.

The performance of these cameras was highly satisfactory. They yielded sharp images, which are of sufficient size to permit quite accurate determinations of intensity to be made.

Four sets of negatives were secured with these instruments, with exposures of 1, 4, 20, and 115 seconds. Of these the 1-second and 115-second series are unsuitable for the best

results, owing partly to the diffused light from the clouds, which affected the sky background differently in the different cameras. This effect was enhanced in the case of the first series by some of the slides having been drawn unnecessarily early.

The 4-second and 20-second series are well suited for accurate determinations of the amount of polarized light in the inner-middle and middle corona. No numerical results have yet been obtained, as special apparatus is necessary for the photometric measurement of these negatives. The polarization is well marked, however.

An effort was made to compare the brightness of the corona with that of the full Moon by impressing a series of standard squares near the ends of two dry plates, with the Moon as the source of light, and then exposing the central portion of each plate to the light of the corona in a suitable camera, *without any lens.* This camera was arranged to admit the light from a circular area of sky 4° in diameter, the corona being in the center.

Two exposures were made during the eclipse of 14 seconds and 50 seconds, respectively.

It will be necessary to determine the effect of the clouds and of the sky background before any definite result can be arrived at.

The negatives were developed at the station on the four days and nights following the eclipse, simultaneously with the dissecting and packing of the instruments. It was a satisfaction to find so large a proportion of the photographs of such excellent quality, notwithstanding the clouds. A cloud of any kind over the Sun at an eclipse looks pretty thick to those who have been preparing for fourteen months to observe the event!

The photographs and instruments, carefully packed for the long journey home, were shipped from Alhama on the evening of September 3d to Barcelona and thence by steamer sailing directly to New York. Farewell visits to the officials of Alhama, the settling of accounts, and the closing of a voluminous correspondence terminated our eclipse duties abroad.

An eclipse expedition to a distant country is a complex matter. A large number of delicate scientific instruments are to be made ready, and tested at home, with reference to their fitness for securing observations demanded in the solution of definite solar problems. Their transport by wagon, rail, and ship to and from the distant station, to insure that they shall arrive safely and on time, must be the subject of much thought and anxiety. The construction and operation of the station will require hundreds of tools and items of supply, and to have them one must take them with him. There are the observers to arrange for and train to the programme. All the instruments and all the observers must do their parts, not at some time when it is convenient, but on a given day, minute, and second. The astronomer charged with the duty of bringing these things to pass is an optimist, for at all points where he needs assistance there are men ready to help him.

The Crocker expeditions are deeply indebted to many institutions and people.

During the months preceding the departure from Mt. Hamilton the Director was especially indebted to His Excellency WILLIAM MCGREGOR, Governor of Newfoundland; to Hon. BENJAMIN H. RIDGELY, U. S. Consul-General at Barcelona; and to Captain H. G. LYONS, R. E., Director-General of the Egyptian Survey; all of whom frequently supplied information of great value.

Harvard College Observatory loaned four intramercurial lenses for use in Labrador.

Princeton University loaned a lens, 5 inches aperture, 40-foot focus, for use in Labrador.

The University of Illinois loaned a sextant and a thermograph for use in Labrador.

The Yerkes Observatory loaned a 16-inch cœlostat complete for use in Spain.

The Solar Observatory of the Carnegie Institution loaned a thermograph for use in Spain.

The U. S. Naval Observatory loaned a 5-inch lens, focal length 40 feet, for use in Egypt.

The Santa Clara College loaned a sextant for use in Egypt.

The following gentlemen arranged for the satisfactory transport of observers and freight from San Jose to New York and return:—

Mr. JAMES HORSBURGH, Jr., Assistant General Passenger Agent; Mr. G. W. LUCE, General Freight Agent; and Mr. PAUL SHOUP, District Freight and Passenger Agent; all of the Southern Pacific Company.

Mr. L. J. SPENCE, General Eastern Freight Agent, Southern Pacific Company, and many of his staff assisted with the freight in and through New York. Mr. PENNELL, Dock Superintendent of the White Star Line extended favors in the transport of the Spanish and Egyptian freight.

Mr. JAMES J. ROCHE, U. S. Consul at Genoa, had all arrangements made for a quick transfer of instruments and baggage to the steamer for Barcelona, if the "Romanic" had arrived before the hour of sailing.

Sig. CARLO FIGARI, of Genoa, obtained information and accommodations for the party and equipment on the steamer "Jativa" from Genoa to Barcelona, and otherwise assisted in the transfer.

Special mention must be made of the help afforded by Mr. BENJAMIN H. RIDGELY, U. S. Consul-General at Barcelona, in supplying a great deal of accurate information in the months preceding our departure from Mt. Hamilton, in expediting the importation and exportation of the instruments, and in arranging for the purchase of lumber and many other supplies. His experience was wide, his judgment was excellent, and his assistance was always efficient. We depended upon him in many ways.

His Excellency WM. MILLER COLLIER, the American Ambassador at Madrid, and Mr. MADDEN SOMMERS, American Vice-Consul at Madrid, responded efficiently to requests for information or advice.

Mr. E. J. MOLERA, of San Francisco, formerly of Spain, long a valued friend of the Observatory, and a past President of the Astronomical Society of the Pacific, held the needs of this expedition in mind from more than a year before preparations began until it was ready to leave San Francisco. He did us many valuable services in this country, still other services in

Spain, and his thoughts were with us throughout our stay in his native land.

Mr. MOLERA'S friend, Professor CASARES, of the Central University, Madrid, whom we had the pleasure of seeing on Mt. Hamilton two years ago, and the latter's friend, Sr. D. ARTURO CUYÁS, who had lived in New York for forty years, together met Mr. CAMPBELL in Madrid before the station was selected and inaugurated several plans that proved helpful. At their request the Minister of the Interior telegraphed to the Governor of the Province of Zaragoza that we were coming into his territory, and asked that he issue suitable instructions to the Alcalde of Alhama to supply our wants as far as possible. In the same way instructions were issued to the Guardia Civil to have an eye to our safety wherever our work might carry us. Sr. CUYÁS and Professor CASARES kept us in mind during our entire stay in Spain, and came to help in the observations. The expedition is deeply indebted to these gentlemen.

Sr. D. V. LUIS, Director-General of the Madrid, Zaragoza, and Alicante Railway, arranged most kindly to expedite the shipments of the apparatus from Barcelona to Alhama and return, by ordering that they should come by "mixed train," instead of by slow freight, without additional expense.

To Director IÑIGUEZ, of the Madrid Observatory, we were indebted for time signals and other scientific favors.

Sr. D. LISARDO HERRANZ, Alcalde of Alhama, and Sr. D. ENRIQUE IBAÑEZ, the extremely capable Secretary of the Municipality, were deeply interested in the expedition, its work, and its requirements, and were constant in their efforts to make it a complete success. Through their kind offices were made all the arrangements to meet the local material wants of the expedition. They never permitted many days to pass without inquiring as to the progress of the preparations and as to whether there was any help they could give.

The expedition received frequent favors from the telegraphic offices of the Government,—Sr. D. FELIPE HERREROS, Agent at Alhama, to whom our thanks are due.

Acknowledgments are due to the members of the Guardia Civil, Srs. BARBAJOSSA and BLASCO, who went beyond the letter of their instructions in their zeal to avoid any misfortunes to the instruments from mischief-makers or otherwise.

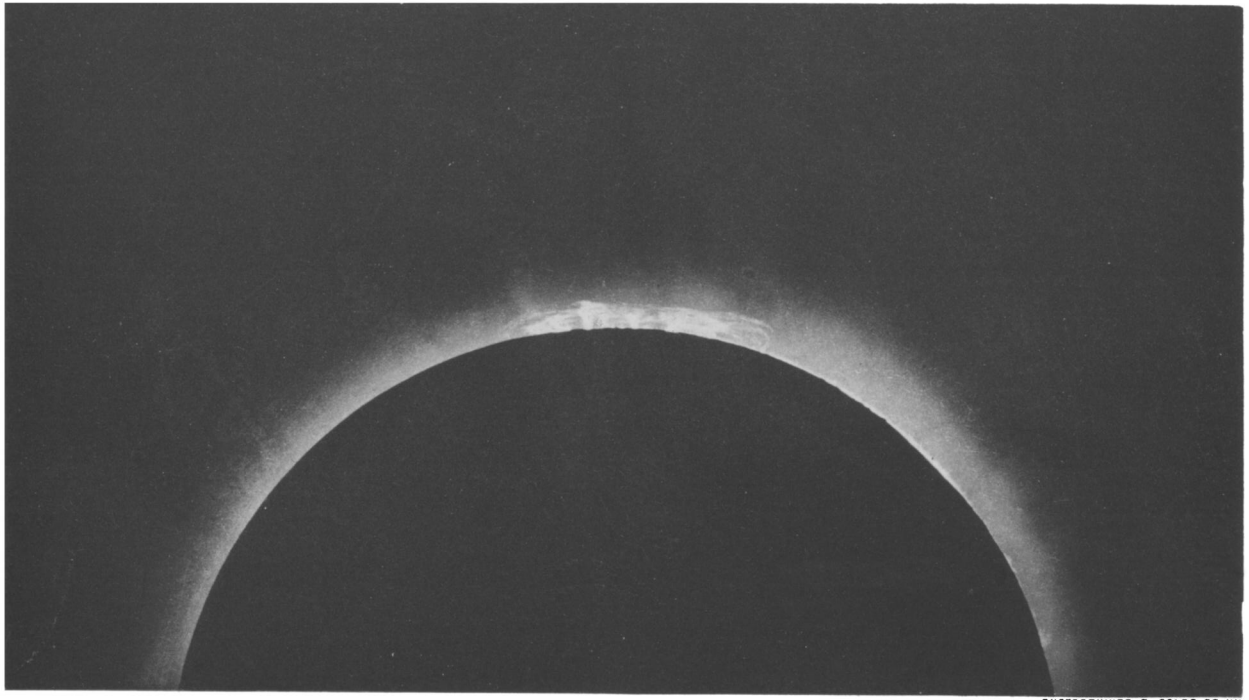
The laborers recommended to us were splendid. They were willing, prompt, strong, and intelligent. To the interested help of José, VICENTE, JUAN, and SEBASTIAN the expedition owed much.

To the gentlemen who journeyed from northern Europe, from the cities and universities of Spain, and to those citizens of Alhama who gave of their time in order to assist in the observations, we desire to offer special thanks.

Relieved of responsibilities at the close of eclipse duties, we were psychologically ready to enter upon vacation journeys. These were entirely apart from the eclipse expedition, and had for their principal purpose the paying of visits to many of the astronomers and observatories of Europe. In common with ourselves, several Dutch, English, French, German, and Italian astronomers who had eclipse stations in various parts of Spain journeyed to Madrid after the event was past, where all attended a splendid banquet given for them by the Municipality of Madrid, presided over by the Alcalde, Sr. D. EDUARDO RIGUERA. Many attended a bull-fight as guests of the city.

At the end of a few days in Madrid, Mr. and Mrs. PERRINE traveled by way of Granada and Gibraltar to Naples for a trip through Italy, Switzerland, Germany, Holland, and England. Mr. and Mrs. CAMPBELL went northward by way of El Escorial and Burgos to Switzerland and down the Rhine to attend the Solar Conference in Oxford; thence to central Germany and Pulkowa, returning again to England to sail from Liverpool on November 1st in company with Mr. and Mrs. PERRINE.

The effects of the three expeditions reached Mt. Hamilton late in November, all in good order.



THE SOLAR CORONA AND PROMINENCES

AUGUST 30, 1905

CROCKER ECLIPSE EXPEDITION, ALHAMA, SPAIN.

THE FORTY-FOOT CAMERA AND INTRAMERCURIAL APPARATUS AT ELEPHANTINE ISLAND.